

Time-Course Spin-Echo and Gradient-Echo EPI of the Human Brain during a Breath Hold

P. A. Bandettini*, E. C. Wong*, R. S. Hinks†, and J. S. Hyde*

*Dept. of Radiology, Medical College of Wisconsin, Milwaukee, WI and †GE Medical Systems, Milwaukee, WI

PURPOSE:

In this study, signal modulation in gray and white matter by a sustained breath hold valsalva maneuver (1) is observed using time course spin-echo and gradient-echo echo-planar imaging (EPI). The potential reasons for observed differences in the characteristics of signal modulation between the spin-echo and gradient-echo sequences are discussed.

INTRODUCTION:

Recent work has demonstrated oxygenation-sensitive contrast in the brain using gradient-echo EPI (2). The paramagnetic contribution of deoxyhemoglobin affects the susceptibility of whole blood. Microscopic B_0 field inhomogeneities (ΔB_0) within and around vessels are created by the susceptibility differential between blood and tissue. It has been postulated that spin dephasing due to ΔB_0 on the microvessel-size spatial scale is best modelled as an intermediate exchange regime (3). In this regime, a spin-echo is attenuated by irreversible dephasing due to diffusion of spins through ΔB_0 , which is refocused by the π pulse, while a gradient-echo is additionally attenuated by diffusion-independent dephasing because ΔB_0 is not refocused. The relative contribution of these effects to signal attenuation is primarily related to the physical size, volume fraction, and susceptibility of the source of ΔB_0 , as well as the diffusion coefficient of spins in the vicinity of ΔB_0 . To begin to understand the relative contribution of these effects it is necessary to directly compare modulation of spin-echo and gradient-echo signal during a vascular stress.

METHOD:

Imaging was performed on a clinical GE 1.5-T Signa system using a 30.5 cm i.d.three-axis local gradient coil. Blipped, gradient-echo and spin-echo EPI pulse sequences ($TE=50ms$, $FOV=24cm$) were used. Acquisition time for each image was 40 ms. Image resolution was 64×64 . A series of 128 sequential images in either the axial or coronal plane was obtained using an interscan delay of 2 s.

During each time course series, the subjects breathed normally for the first 40 scans, then inhaled deeply and held their breath. Exhalation occurred after 25 to 40 scans. The subjects breathed normally for the remainder of the series.

RESULTS:

Signal intensity from 4×4 voxel regions in white and gray matter were plotted as a function of image number. Figures 1 and 2 show plots from a typical experiment. The attenuation in white matter was not large enough for comparison. Gray matter attenuation in the spin-echo sequence was spatially homogeneous while the maximum attenuation in the gradient-echo images appeared to occur primarily in the gray matter areas having higher large vessel density (sinuses and temples). The decrease in signal in the gray matter in the spin-echo sequences was approximately half that of the regions of largest gray matter attenuation in gradient-echo sequences.

CONCLUSIONS:

The sudden signal drop observed in gray matter may be explained by the nature of the valsalva maneuver. The increased pressure in the lungs impedes venous return, slightly increasing global cerebral blood volume. Average cerebral blood oxygenation be decreased due to the relative increase in venous blood volume and to the onset of hypoxia during the breath hold.

Since attenuation is apparent in the spin-echo sequence, diffusion of spins through susceptibility induced field gradients appears to be demonstrated. Since gradient-echo EPI demonstrates twice the attenuation of spin-echo EPI in gray-matter regions, it is apparent that an additional static dephasing effect also occurs, demonstrating that the intermediate regime is a correct assumption. The regional variations in gray matter attenuation observed in areas of higher large vessel density using the gradient-echo sequence and the relative homogeneity within gray and white matter using the spin-echo sequence suggests that a gradient-echo is more sensitive to susceptibility differentials from larger vessels while a spin-echo is more sensitive to susceptibility variations from the more homogeneously-distributed smaller vessels.

The sudden, regionally selective, and pulse-sequence sensitive drop in signal during the breath hold is a surprising new finding which reveals further information about the nature of deoxyhemoglobin-related signal modulation. The subtraction of a spin-echo image obtained during the breath hold from a spin-echo image obtained during recovery creates an image where contrast is based upon what may be closely related to blood perfusion volume.

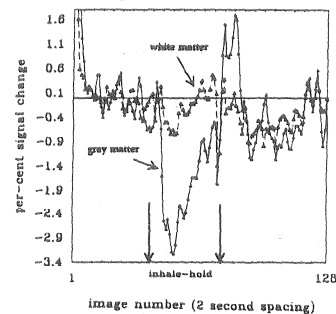


Figure 1 gradient-echo epi

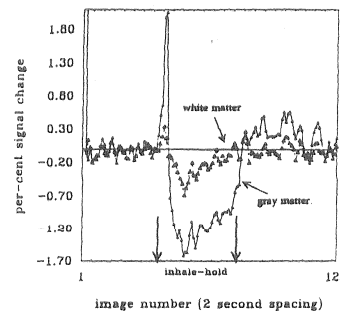


Figure 2 spin-echo epi

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